The relationship of silver content on water flux of polysulfone composite membrane

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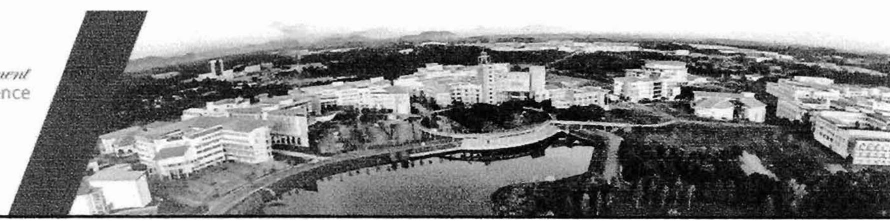

Acknowledgement

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Objective

- The present effort focuses on the improvement of polysulfone (PSF)-based membrane by incorporating silver nitrate ($AgNO_3$). It is expected that the addition of such materials will improve membrane separation performance.

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Literature review

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- Water plays a very important role in human life. It is used in different fields like domestic usages, energy production, recreation, industry and agriculture. However, water pollution is one of the major environmental problems in the world. As demands for drinking water are scare, water treatments are more focused nowadays. There are various techniques used for polluted water treatment such as
  - precipitation of chemical agent,
  - adsorption on activation carbon,
  - ion-exchange on resins
  - membrane processes.

L. Phelane, F. N. Muya, H. L. Richards, P. G. L. Baker, and E. I. Iwuoha, "Polysulfone Nanocomposite Membranes with improved hydrophilicity," *Electrochim. Acta*, vol. 128, pp. 326–335, 2014

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- Membrane technology is widely applied for water treatment and receives significant attention due to its outstanding process for the removal of
  - particles,
  - turbidity
  - microorganisms
- However, the small size of viruses and the relatively large pore size of the membrane are the factors that restrict an efficiency of Microfiltration (MF) and Ultrafiltration (UF) membrane. Moreover, the imperfection of membrane surface also can increase the possibility of microbacteria penetration during filtration.

I. Sawada, R. Fachrul, T. Ito, Y. Ohmukai, T. Maruyama, and H. Matsuyama, "Development of a hydrophilic polymer membrane containing silver nanoparticles with both organic antifouling and antibacterial properties," *J. Memb. Sci.*, vol. 387–388, no. 1, pp. 1–6, 2012

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- The few factors that define a membrane's effectiveness are
  - permeability,
  - pore structure
  - Selectivity
  - Hydrophilicity
  - mechanical stability.
- Nanoparticles in membrane manufacturing allows for both a high degree of fouling control and the ability to produce a desirable membrane structure.
- Polymeric membranes are favored for their ease of fabrication and their low cost, however, their disadvantages are that the polymers most commonly used, namely polysulfone (PSf) which are semi-hydrophobic which can lead to reduced flux and increased fouling

M. Perez, "Florida State University Libraries The Effects of Silver Nanoparticles on Wastewater Treatment and Escherichia Coli Growth," 2012
E. Science, R. Article, and L. Angeles, "A Review of Water Treatment Membrane Nanotechnologies," 2010

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- silver nanoparticles are widely known to be antimicrobial, and there are commercial home water systems currently available which use membranes or filters coated with silver nanoparticles, and these are reported to remove 99.99% of pathogens. They have also been shown recently to improve hydrophilicity in polymeric membranes and change the porous structure of membranes.

Q. Li, S. Mahendra, D. Y. Lyon, L. Brunet, M. V Liga, D. Li, and P. J. J. Alvarez, "Antimicrobial nanomaterials for water disinfection and microbial control : Potential applications and implications," *Water Res.*, vol. 42, no. 18, pp. 4591–4602, 2008
J. Li, X. Shao, Q. Zhou, M. Li, and Q. Zhang, "Applied Surface Science The double effects of silver nanoparticles on the PVDF membrane : Surface hydrophilicity and antifouling performance," vol. 265, pp. 663–670, 2013
A. Mollahosseini, A. Rahimpour, M. Jahamshahi, M. Peyravi, and M. Khavarpour, "The effect of silver nanoparticle size on performance and antibacteriality of polysulfone ultra fi ltration membrane," DES, vol. 306, pp. 41–50, 2012

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- Polyethyleneimine (PEI) can be used as a stabilising agent and reducing agent. In this study PEI was used as stabilizing agent for silver nanoparticles formation. In addition, PEI can increase the hydrophilicity of bonded materials in the separation and detection of biological samples particularly in reducing nonspecific adsorption significantly and act as water soluble additives.

H. Zhang, H. Mao, J. Wang, R. Ding, Z. Du, J. Liu, and S. Cao, "Mineralization-inspired preparation of composite membranes with polyethyleneimine-nanoparticle hybrid active layer for solvent resistant nanofiltration," J. Memb. Sci., vol. 470, pp. 70–79, 2014
Z. Fan, Z. Wang, N. Sun, J. Wang, and S. Wang, "Performance improvement of polysulfone ultrafiltration membrane by blending with polyaniline nanofibers," J. Memb. Sci., vol. 320, no. 1–2, pp. 363–371, 2008
Y. Xue, W. Shi, B. Zhu, X. Gu, Y. Wang, and C. Yan, "Polyethyleneimine-grafted boronate affinity materials for selective enrichment of cis-diol-containing compounds," Talanta, vol. 140, pp. 1–9, 2015

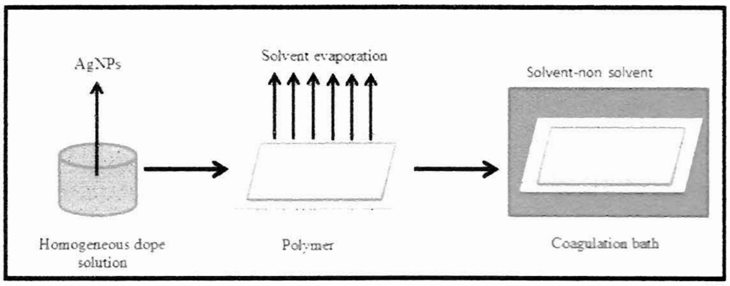
Experimental

Material

- Polysulfone pellets (PSf with M_W = 35 kDa)
- Polyethylenimine branched (PEI with M_W = 25 kDa)
- N-Methyl-2-pyrrolidone
- Powdered activated carbon
- Silver Nitrate

Membrane Preparation

- The flat sheet polysulfone (PSf) membranes are prepared by using a wet phase inversion method. About 0.3wt% of PEI, 15% PSf and 0.5 wt%AC were solubilize in NMP (85 wt%) and the solution was magnetically stir for 7 hours to form a homogenous solution at 40 °C. The lid of the container was kept close to prevent the solvent loss due to evaporation during the whole stirring process (360 rpm)



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Different amounts of silver nitrates (AgNO3) were separately dissolved in 3.0 ml of NMP. These solutions were added to the PSf solution in order to obtain different AgNP content membrane casting solutions. NMP was acts as a reducing agent for the formation of the AgNP. Table 1 shows the composition of all the membranes

Membrane	Composition (wt %)				
type	$AgNO_3$	PSf	PEI	NMP	AC
CM A	-	15.0	-	85.0	-
CM B	0.5	15.0	0.3	83.7	0.5
CM C	1.0	15.0	0.3	83.2	0.5
CM D	1.5	15.0	0.3	82.7	0.5
CM E	2.0	15.0	0.3	82.2	0.5
CM F	-	15.0	0.3	84.2	0.5

Flux measurement

- The performance of prepare membrane was characterized by measuring the water flux. The ultrafiltration experiments were setup using a laboratory scale dead-end system at room temperature which is Stirred Ultrafiltration Cell (Model 8050, Millipore Corp., Bedford, MA) with a total internal volume of 50 ml and active surface area of 13.4 cm^2.
    1. membrane with radius of 44.5 mm was soaked in the deionized water to facilitate the filtration process for 30 minutes.
    2. membrane was fixed between two steel parts and also sealed with an O-ring. The deionized water was used as feed solution. A magnetic stirrer was placed under the membrane cell to stir the feed.
    3. flux of membranes was measured during 10 minutes filtration and compact at 1-3 bar.

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- The membrane permeate flux was measured continuously by collecting the permeate water and measuring its volume at regular intervals. The experiments are carry out at room temperature and the pressure of 1-3 bar supplied by compressor. The membranes fluxes were calculated as follows:

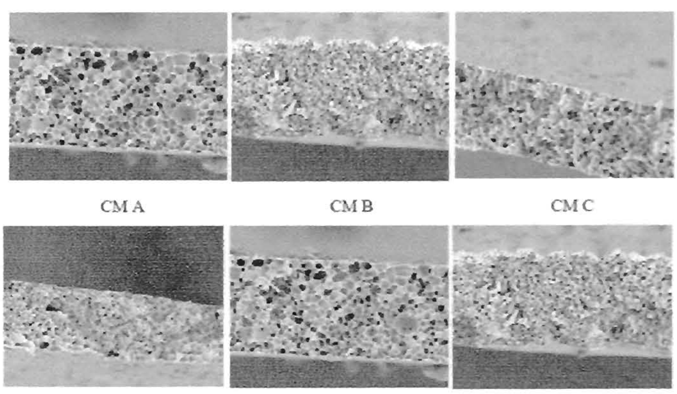
$$\boxed{J_o = \frac{V}{A\Delta t}}$$

Where J_0 is pure water flux ($Lm^{-2}\ h^{-1}$). Q is the permeate volume (L). A is the membrane area (m^2) and Δt is the time(h).

J. Li, X. Shao, Q. Zhou, M. Li, and Q. Zhang, "Applied Surface Science The double effects of silver nanoparticles on the PVDF membrane : Surface hydrophilicity and antifouling performance," vol. 265, pp. 663–670, 2013

Result and Discussion

Membrane Morphology



CM A CM B CM C

CM D CM E CM F

SEM Image for Cross Section Morphology (1500 magnification, 50 µm) (CM A) pure PSf membrane, (CM B) 0.5 wt % silver content, (CM C) 1.0 wt % silver content, (CM D) 1.5 wt % silver content, (CM E) 2.0 wt % silver content and (CM F) 0 wt% silver content

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- All the composite membrane exhibits the typical symmetric structure with sponge like structure. In the finding of Ananth et al., (2012), the sponge like structure might due to the hydrophilic of PEI absorbed water and extensive diffusion occurs from intra molecular hydrogen bonding non solvent and functional groups of membrane during phase separation.
- As silver concentration in composite membranes increased, the viscosity of the casting solution also increased due to increased nanoparticle or polymer ratio. The viscosity of casting solution plays major part in phase inversion because it affects the solvent-nonsolvent exchange rate as well as morphology of the membranes.
- The addition of silver nitrate could promote the formation of macrovoids in the membrane. There was no macro voids on the cross section of membrane as observed from CM A due to the pure PSf membrane morphology. Similar observations were obtained from previous study observed cross–section morphology of composite membranes displayed macro voids as the addictive percentage increased and Vatanpour et al. (2015) found macrovoids were expanded in number and size with increasing the amount of silver.

Ananth, G. Arthanareeswaran, and H. Wang, "The influence of tetraethylorthosilicate and polyethyleneimine on the performance of polyethersulfone membranes," *Desalination*, vol. 287, pp. 61–70, 2012
M. Sile-Yuksel, B. Tas, D. Y. Koseoglu-Imer, and I. Koyuncu, "Effect of silver nanoparticle (AgNP) location in nanocomposite membrane matrix fabricated with different polymer type on antibacterial mechanism," Desalination, vol. 347, pp. 120–130, 2014
V. Vatanpour, A. Shockravi, H. Zarrabi, Z. Nikjavan, and A. Javadi, "Fabrication and characterization of anti-fouling and anti-bacterial Ag-loaded graphene oxide/polyethersulfone mixed matrix membrane," J. Ind. Eng. Chem., vol. 30, pp. 342–352, 2015
S. R. Panda and S. De, "Preparation, characterization and performance of ZnCl2 incorporated polysulfone (PSF)/polyethylene glycol (PEG) blend low pressure nanofiltration membranes," Desalination, vol. 347, pp. 52–65, 2014

Continue (Flux)

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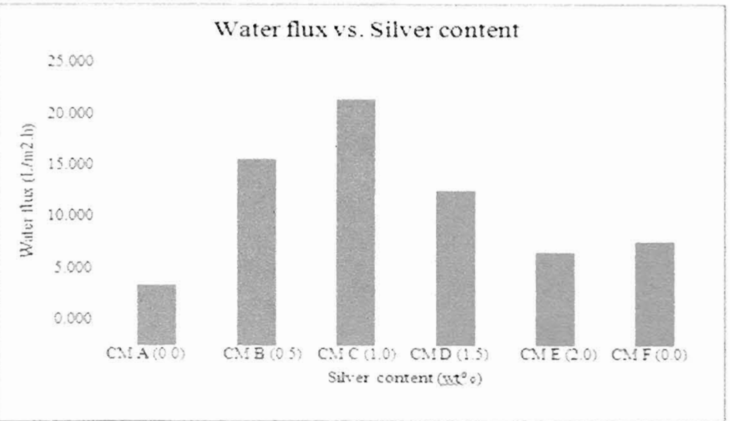
- For any membrane filtration process, water permeability is the most important parameter in determining the performance of the membrane. Stirred Ultrafiltration Cell was used to study the flux of composite membrane with different silver loading. The flux is used to express the rate at which water permeates a membrane barrier ($L/m^2.h$). The change in permeability is presented to demonstrate the effect of modification.



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- Previous research showed that by increasing the concentration of silver nanoparticles on the membrane resulting low water flux due to barrier created by the presence of silver nanoparticles or agglomeration of nanoparticles on the membrane surface.
- The agglomeration of the silver occurs due to the formation of crystalline silver particle in this research which leads to low water permeate. This observation was in agreement with the study of where the addition of silver nitrate in the dope solution attributed to the high crystallinity of silver nanoparticle.
- The pure water flux for CM F was higher than CM A due to additional of PEI which increase the membrane hydrophilicity compared to CM A.

Sawada, R. Fachrul, T. Ito, Y. Ohmukai, T. Maruyama, and H. Matsuyama, "Development of a hydrophilic polymer membrane containing silver nanoparticles with both organic antifouling and antibacterial properties," *J. Memb. Sci.*, vol. 387–388, no. 1, pp. 1–6, 2012
M. Gultekinoglu, Y. Tunc Sarisozen, C. Erdogdu, M. Sagiroglu, E. A. Aksoy, Y. J. Oh, P. Hinterdorfer, and K. Ulubayram, "Designing of dynamic polyethyleneimine (PEI) brushes on polyurethane (PU) ureteral stents to prevent infections," Acta Biomater., vol. 21, pp. 44–54, 2015
H. Basri, "Development of Hybrid Antibacterial Membrane By Incorportang Silver Particle...", M.S Dissertation, Dept. of Chemical Engineering, Universiti Teknologi Malaysia, 2012

conclusion

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- Surface pore size, cross-section morphology, skin layer thickness, and hydrophilicity contribute to a membrane's permeability and rejection properties, and in nanocomposite mixed matrix membranes, surface modification with nano-sized particles is used to alter these membrane properties.
- In this study, the Ag-PSf/PEI membranes were successfully fabricated. Ag-PSf/PEI membrane with good hydrophilicity performance was prepared via phase inversion method. Morphologies and filtration performance of the membrane were investigated. The morphologies of membrane were improved significantly, where the porosity and pore size played a great role in the filtration of membranes. The water flux of blended membrane with 1.0% of Ag-PSf/PEI hybrid membrane was four times higher than that of the pure PSf membrane.

J. Li, Z. Xu, H. Yang, L. Yu, and M. Liu, "Applied Surface Science Effect of TiO 2 nanoparticles on the surface morphology and performance of microporous PES membrane," vol. 255, pp. 4725–4732, 2009

Thank You for your attention

Prof. Dato' Dr Kamaruzzaman Sopian
Director, Solar Energy Research Institute, Universiti Kebangsaan Malaysia

RECENT ADVANCES IN SOLAR THERMAL ASSISTED AIR CONDITIONING SYSTEMS FOR HOT AND HUMID AREAS
Date: 13th September 2017

ract:
thermal air conditioning refers to any air conditioning or cooling system that uses thermal energy. The most common solar assisted air conditioning systems are rption, adsorption and desiccant cooling system. The disadvantages of solar ıal air conditioning system compared to the conventional vapor compression are many additional components and also large solar collector area. The main ıntage of solar thermal air conditioning system is that it uses less electricity and uses ıal energy. Three advanced solar cooling systems have been developed (a) a adsorption system (b) solar absorption system with flash tank and ejector and with fluids for heat transfer enhancement and (c) liquid and solid desiccant cooling ms. The way forward for solar thermal cooling technology is the development of compact design that will enable the usage of less collector area with the same rmance making it more cost competitive.

Professor Ir Dr Farid Nasir Ani
P.Eng, MINDS, FSOE(UK), FIPlantE(UK), MIMarEST(UK), C.Eng, MASHRAE,
ıustainable and Renewable Energy Research Group (SURE),
culty of Mechanical Engineering, Universiti Teknologi Malaysia

ROWAVE INDUCED THERMAL PROCESSING OF BIORESOURCES
Date: 14th September 2017

ıct:
y crisis and continuously fluctuating cost of petroleum have move attention of chers toward renewable and sustainable energy and materials sources. Biomass esources are available in abundantly and cheap sources that are environment y in tropical countries. It has been identified as one of the main sources of the susıle and renewable energy in Malaysia. One example of utilization of biomass is in ocessing of palm oil in Malaysia. The presentation describes several possible to provide energy as well as potential value-added products from bioresources. end in thermo-conversion processing of the biomass is the application of vave energy into renewable biofuels, materials and chemicals. The potential f agro-products and agro-solid wastes for biofuels, materials and chemicals are ıhted. The applications of these renewable sources to produce biofuels, materials hemicals have been applied in some countries around the world. The implemenof the biomass technology will be feasible and able to utilize when the technoldeveloped, fabricated and commission locally with locally produced biomass. ıdvanced research and development efforts, together with local expertises, nous technologies could be produced, thus reducing the high cost of import ology.

Prof Dr Mustafizur Rahman
Department of Mechanical Engineering, National University of Singapore

INNOVATIONS IN TOOL-BASED HYBRID/COMPOUND MICRO/NANO-MACHINING FOR SUSTAINABLE MANUFACTURING – AN INTEGRATED APPROACH

Date: 13th September 2017

Abstract:
In recent years, there has been a remarkable development in manufacturing technologies and design of machine tools. This is in tandem with greater demand for better performance quality of products. Both 'revolutionary' and 'evolutionary' innovations are the keys to meet the challenges posed by the needs of functional requirement of products, miniaturization, and industrial realization of micro/nanotechnology. These limitations can be overcome by taking an integrated approach towards innovation through: (1) compound machining processes, and (2) development of proper machine tools supporting such machining processes to meet the demand for machining difficult-to-cut materials with quality and complexity.

Conventional machining processes (material removal processes, such as turning and milling), have been hybridized or compounded with non-conventional machining processes like EDM (electro discharge machining), EDG (electro discharge grinding), ECM (electro chemical machining), wire-EDM and Laser to fabricate micro-structures with high dimensional accuracy, and such processes are termed as 'compound machining'. In order to achieve meaningful implementation of compound machining techniques, understanding of process physics to provide relevant background for modeling, measurement and identification of control parameters are of utmost importance. Implementation of this concept can be successfully carried out through the adaptation of Digital Manufacturing.

For successful implementation of such compound machining technique, design and development of machine tools capable of such complex machining (i.e. turning, milling, EDM, laser, etc. on the same machine and setup) are needed.

An integrated approach for successful implementation of material, manufacturing processes and design can only be achieved through a paradigm shift in thought and processes of conventional machining. This shift can only be materialized through revolutionary innovation rather than an evolutionary one.

An attempt has been made in this presentation regarding the mindset, activities and achievements of the author, his group members at National University of Singapore (NUS), and some research partners in other parts of the world for successfully achieving this objective.

Dr Pierre Barroy
University of Picardie Jules Verne, France

SURFACE ENGINEERING PLASMAS FOR ENHANCED TECHNOLOGIES AND GREENER SOCIETIES

Date: 14th September 2017

ract:

With an expanding world population on a finite Earth, resources have been ily diminishing. Bulk materials are now in high demand everywhere and the and in functionalities cannot be met by those materials anymore. Introduc- urface functions on bulk materials can enable much needed resource gs and more efficient use of energy sources.

In this review, we will present a survey of this field with an emphasis on ve systems using an interaction with their environment for energy gains in par- ar. Many environmental stimuli be tapped by smart surfaces made from physically interacting materials. cally, parameters such as temperature, humidity, or illumination are such inter- g stimuli.

Here, we will review existing and promising solutions brought thanks to na processing. Non-equilibrium plasmas enable low-temperature, tailored gy delivering to surfaces and we will review in particular combined effects can be exploited, for renewable energies or property enhancements in ral resources, such as smart blades for water turbines.

FLOOR PLAN